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ABSTRACT

This paper continues a research agenda to investigate teachers' beliefs about mathematics, mathematics learning, and mathematics teaching. Focus is given to data collected in 1996 and 1997 investigating the views of more than 900 primary and secondary mathematics teachers in the southwestern suburbs of Sydney and the North Coast of New South Wales towards the use of manipulatives in the teaching and learning of mathematics. Current mathematics curriculum documents support the availability and use of manipulatives by students and teachers in their mathematics teaching and learning through all school years. This paper provides data on the current use of manipulatives in the surveyed primary and secondary schools and compares primary and secondary mathematics teachers' responses about their use of manipulatives in the teaching and learning of mathematics. Questions about the effect of differences in this use on the transition of students from primary to secondary schools are also addressed. (Contains 28 references and 9 tables). (Author/NB)

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Mathematics and manipulatives: Comparing primary and secondary mathematics teachers' views[1]

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Abstract

This paper continues the authors' research agenda to investigate teachers' beliefs about mathematics, mathematics learning and mathematics teaching. Focus is given to data collected in 1996 and 1997 which investigated the views of more than nine hundred primary and secondary mathematics teachers in the south western suburbs of Sydney and the North Coast of New South Wales towards the use of manipulatives in the learning and teaching of mathematics. Current mathematics curriculum documents support the availability and use of manipulatives by students and teachers in their learning and teaching of mathematics through all school years. This paper provides data on the current use of manipulatives in the surveyed primary and secondary schools and compares primary and secondary mathematics teachers' responses about their use of manipulatives in the learning and teaching of mathematics. Questions about the effect of differences in this use on the transition of students from primary to secondary schools will be addressed.

Introduction

Data concerning the use of manipulatives in primary school mathematics classes and their relationship to teachers' beliefs about mathematics, mathematics learning and mathematics teaching have been analysed and reported in earlier papers (Perry & Howard, 1994; Howard & Perry, 1997; Howard, Perry & Conroy, 1995; Perry, Howard & Conroy, 1996). Similar data pertaining to secondary mathematics teachers has also been reported by the authors (Howard, Perry & Lindsay, 1996, 1997).

This paper seeks *to identify and compare current teacher usage of concrete materials (manipulatives) in primary and secondary school mathematics learning and teaching and reasons for this use, in a sample of government and Catholic schools in South Western Sydney and on the North Coast of New South Wales.*

Background to the study

For the most part, the terms 'concrete materials' and 'manipulatives' are taken as synonymous to mean 'concrete models that incorporate mathematical concepts, appeal to several senses and can be touched and moved around by students" (Hynes, 1986, p.11). Such models have a long history in mathematics education (Szendrei, 1996). Manipulatives play an important role in the learning and teaching of mathematics in primary schools (Atweh & Watson, 1992; Australian Council for Educational Research, 1965; Australian Education Council, 1991, 1994; Ball, 1992; Grouws, 1992; National Council of Teachers of Mathematics, 1980, 1989, 1991; NSW Department of Education, 1969, 1972, 1989). The role is much less understood in secondary school mathematics learning and teaching (Howard, Perry & Lindsay, 1996).

There has been a great deal of support for the use of manipulatives in the learning and teaching of mathematics (Bohan & Shawaker, 1994; Sowell, 1989; Thompson, 1992). It has been reported that the use of manipulatives in mathematics learning and teaching decreases as children move through the primary grades (Gilbert & Bush, 1988; Hatfield, 1994; Howard & Perry, 1997; Suydam, 1984, 1986). Hence, it is not surprising that this trend continues into secondary schools (Howard et al, 1996).

Methodology

Data have been collected on primary and secondary teachers' perceptions of their acceptance and use of manipulatives in their mathematics classrooms. In particular, data have been collected and analysed to help answer the following questions:

1. What manipulatives are employed in the learning and teaching of mathematics in primary and secondary schools?
2. How are these manipulatives used?
3. What factors influence the choice of primary teachers and secondary mathematics teachers to either use or not use manipulatives in their mathematics lessons?
4. Are there differences in the use of manipulatives across different mathematical topics?

The data were collected using a specifically designed questionnaire consisting of both multiple choice and open-ended questions covering the following areas:

1. subject demographics such as gender, age, position in school, nature of teacher training, length of teaching experience, class(es) currently taught, class size, classes taught over the last ten years;
2. use of manipulatives in mathematics learning and teaching such as which are used, why and how they are used, and the areas of mathematics in which they are used;
3. beliefs about mathematics, mathematics learning and mathematics teaching.

The questionnaire relies on the self reporting of the teachers and parallels much of the work reported in Hatfield (1994).

The questionnaire has been administered over 1995, 1996 and 1997 to the samples described in Table 1.

Year	School level	School type	Number of Schools	Responses received
1995	Primary	Government	25	252
1996	Secondary	Government	37	198
1996	Secondary	Catholic	15	51
1997	Primary	Government	114	244
1997	Primary	Catholic	32	107
1997	Secondary	Government	23	44
1997	Secondary	Catholic	12	43

Table 1 Number of schools surveyed and number of responses to questionnaire

In all cases, the questionnaire was posted, with reply paid envelopes, to the Principals of the schools after first making telephone contact to obtain their initial approval to undertake the survey in the schools and to ascertain the number of primary teachers or secondary mathematics teachers in each school. In the secondary schools, telephone contact was also made with the Head Teacher (Mathematics).

Results

In this paper, the data on teachers' use of manipulatives from the 1995 primary school surveys, the 1996 secondary school surveys and the 1997 primary and secondary school surveys are analysed in relation to their demographic data. Data concerning teacher beliefs will be the subject of later papers.

Demographic data

A total of 939 responses are analysed in this paper - 603 primary and 336 secondary teachers. Table 2 shows the gender composition of the sample.

School level	Female	Male
Primary	458 (76%)	143 (24%)
Secondary	138 (41%)	198 (59%)

Table 2 Gender composition of sample (N = 939)

The majority of respondents had 6 or more years of teaching experience, as shown in Table 3.

School level	< 1 year	1 - 5 years	6 - 10 years	11 - 20 years	> 20 years
Primary	13 (2%)	89 (15%)	105 (17%)	199 (33%)	197 (33%)
Secondary	9 (3%)	45 (13%)	57 (17%)	116 (35%)	108 (32%)

Table 3 Teaching experience (N = 939)

The school positions held by the respondents in both primary and secondary schools are reported in Table 4.

School level	Principal / DP / AP	Other executive / Head Teacher (Maths)	Classroom teachers	Other teachers
Primary	120 (20%)	54 (9%)	366 (61%)	59 (10%)
Secondary	10 (3%)	67 (20%)	247 (74%)	11 (3%)

Table 4 Positions held in primary and secondary schools (N = 939)

The majority of teachers in the sample reported that they are qualified at the 3 or 4 year trained level. Some have undertaken postgraduate study and some identified themselves as 2 year trained. Details are given in Table 5.

School level	2 years	3 years	4 years	> 4 years
Primary	53 (9%)	245 (41%)	280 (46%)	24 (4%)
Secondary	3 (1%)	21 (6%)	281 (84%)	29 (9%)

Table 5 Years of teacher education (N = 939)

Use of manipulatives data

A significant number of the secondary respondents (87%) and primary respondents (97%) felt confident in using the manipulatives available to them. However, when asked if they would like more training in the use of manipulatives, 222 (66%) secondary respondents and 281 (47%) of primary respondents indicated that they would.

Of the 603 primary respondents, over half reported the use of manipulatives in each mathematics lessons, whereas only 15 of the 336 secondary respondents reported such regular use. Further details are given in Table 6.

School level	Each lesson	Weekly	Fortnightly	Monthly	Never
Primary	332 (55%)	184 (30%)	45 (7%)	16 (3%)	8 (1%)
Secondary	15 (4%)	87 (26%)	86 (26%)	124 (37%)	18 (5%)

Table 6 Frequency of use of manipulatives in mathematics classes (N = 939)

Table 7 shows the mathematical topics in which the use of manipulatives was reported.

Mathematical topic	Primary	Secondary
Measurement	563 (93%)	293 (87%)
Geometry	562 (93%)	256 (76%)
Number and Algebra	545 (90%)	147 (44%)
Chance and Data	319 (53%)	203 (60%)
Calculus	N/A	26 (8%)
Other	32 (5%)	22 (7%)

Table 7 Mathematical topics using manipulatives
Primary N = 603; Secondary, N = 336 (Multiple responses possible)

The respondents were asked to identify what manipulatives they used in their mathematics classes. The most used structured materials in primary schools were Base 10 blocks (87%), whilst, in the secondary schools, 21% of respondents reported their use. Other manipulatives used by primary school teachers for number were Multilink (55%) and Unifix (54%). This compares with 10% of the secondary teachers reporting the use of Unifix material. The reported use of Cuisenaire materials in the primary school (26%) is higher than expected and suggests the need for further investigation into the ways in which these are used. The use of manipulatives in the teaching of algebra was reported by 37% of the secondary respondents.

In both primary and secondary schools, Pattern Blocks were used extensively (primary 68%, secondary 42%) as were Polydron materials (primary 50%, secondary 38%). Many primary (69%) and secondary teachers (32%) reported the use of environmental materials in their mathematics teaching.

Teachers reported a variety of reasons for using manipulatives in their mathematics lessons. These are shown in Table 8.

Reasons for use	Primary	Secondary
Syllabus mandate	61 (10%)	15 (4%)
Benefit students' learning	569 (94%)	282 (84%)
Students enjoy them	385 (64%)	179 (53%)
School mathematics policy	89 (15%)	28 (8%)

Table 8 Reasons for the use of manipulatives
Primary N = 603; Secondary, N = 336 (Multiple responses possible)

The overwhelming response was that both primary and secondary teachers used manipulatives because they believed that the materials benefit students' mathematics learning. The next strongest response indicated that teachers used manipulatives because they believed students enjoy using them. School mathematics policies and the prescribed syllabus appeared to have minimal impact on most teachers' use of manipulatives in their mathematics lessons.

Ways in which used	Primary	Secondary
Teacher demonstration	501 (83%)	226 (67%)
As students wish	430 (71%)	92 (27%)
As agreed between teacher and students	336 (56%)	197 (59%)
By students to check their work	272 (45%)	64 (19%)
Remedial support	393 (65%)	90 (27%)

Table 9 Ways in which manipulatives are used in mathematics lessons
Primary N = 603; Secondary, N = 336 (Multiple responses possible)

Teachers reported that manipulatives were being used for a variety of purposes in mathematics classrooms. The wide use of manipulatives by teachers for demonstrations in both primary and secondary mathematics lessons was higher than anticipated. Compared to their use in secondary schools, manipulatives were used in primary schools much more as the students wish, for students to check their work and for remedial support.

Analysis and discussion

The frequency of use of manipulatives in secondary mathematics classrooms is significantly lower than that found in primary schools ($p < 0.001$). This is hardly surprising as an analysis of teacher use of manipulatives across the primary school years indicates a significant decrease in this use in Years 5 - 6 when compared with Years K - 4 ($p < 0.05$). It would be reasonable to suggest that this trend would continue in the secondary school.

This trend is further emphasised by considering the frequency of use of manipulatives reported by the respondents. Comparison of the primary and secondary data shows that 55% of primary teachers use manipulatives in each lesson whereas only 4% of all of the secondary respondents do so. Whereas most primary teachers reported that they use manipulatives either weekly or for each lesson, most secondary teachers used them fortnightly or monthly.

There are several reasons which could be put forward for the relatively low rate of use of manipulatives by secondary mathematics teachers. The very structure of many secondary schools, with their rigid timetables, movement of students and teachers around the school and firm, school-wide programs may make it difficult for individual teachers to organise the supply of manipulatives to their classes. The dominance of text book lessons in secondary mathematics classrooms and the ease with which the use of such texts can be arranged could also effect the regular use of manipulatives. The authors have reported on these matters elsewhere (Howard et al, 1996, 1997).

Almost all teachers felt confident in the use of manipulatives available to them but many reported that they would appreciate further training in the use of manipulatives in the mathematics classroom. This could be paraphrased to suggest that "teachers feel confident in using the manipulatives that they know but they also know that they don't know everything they need to know about manipulative use". In particular, much of the acceptance of manipulatives by teachers may be based in practice and have little theoretical underpinning.

Those primary and secondary teachers who do use manipulatives indicated overwhelmingly that they use them primarily because they feel that the manipulatives benefit the students' learning and that the students enjoy using them.

Though a variety of manipulatives is used by secondary respondents, no particular manipulative is used by more than 40% of them. That is, there is not a dominant manipulative in secondary mathematics. This is in stark contrast to the primary schools where 87% of the respondents used Base 10 blocks. No doubt, the importance placed on Base 10 blocks in the K-6 Mathematics Syllabus (NSW Department of Education, 1989), mathematics text books and in professional development has effected this level of adoption.

There were no significant differences identified for the primary teacher respondents in the teacher use of manipulatives in mathematics lessons across the variables of gender, position in school, school system, teaching experience and teacher education. Female secondary mathematics teachers appear to use manipulatives significantly more often than male secondary mathematics teachers ($p < 0.01$). This may be a function of the classes taught rather than a genuine gender difference. No other significant differences across demographic variables for the secondary respondents were found.

Over 50% of both primary and secondary respondents reported the use of manipulatives in their teaching of Chance and Data. Hence, even though there is no curriculum mandate in NSW to teach Chance in the primary years, this study would suggest that many teachers are doing so.

Even though the respondents agree that manipulatives benefit students' learning and students enjoy using them, there are differences between primary and secondary teachers in the ways in which manipulatives are used in mathematics classrooms. While in both levels of schooling, teacher demonstration is the major mode of use, there are obvious differences between the schooling levels "as students wish", "by students to check their work" and for "remedial support". In each of these modes, primary teachers reported a much greater use of manipulatives. Such a change from the primary to secondary years may have implications for some students' learning of mathematics. This transition period has been identified as a concern (Australian Education Council, 1991; NSW Board of Studies, 1988) and it would appear that manipulative use in mathematics learning and teaching in junior secondary school is an issue requiring further investigation.

Conclusion

Since the commencement of this study, the authors have reported on numerous aspects of manipulative use in primary and secondary school mathematics learning and teaching. Extensive data have been gathered which confirms previous research on such manipulative use. However, there have been some surprises. Among these are the number of primary teachers who use Cuisenaire materials despite of their removal from syllabus documents and text books and the penetration of newer materials such as Polydrons and Pattern Blocks.

There is a clearly expressed need by both primary and secondary respondents for further training in the use of manipulatives in their mathematics teaching. This has implications for both pre-service teacher education programs and teacher development sessions. There is an acceptance among teachers that students' mathematical learning benefits from the use of manipulatives. However, this acceptance may not have a solid conceptual base.

This study also suggests a need to develop a greater awareness among secondary teachers of the ways in which manipulatives can be used to support students' mathematical learning during the transition from primary to secondary schooling, particularly as a source of remedial assistance for students and through increasing their availability for students to work with as they wish. This may require an increase in the overall flexibility of secondary mathematics teaching.

Investigation into the actual use of manipulatives in primary and secondary mathematics classrooms through direct observation and interview would allow further analysis of the ways in which manipulatives are currently being used. The authors propose to undertake such a study in 1998.

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